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AERIAL PHOTOGRAPHIC STUDY
OF PLANT DISTRIBUTION AND DISPERSION

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Recognition of the types of vegetation and the types of habitat in the desert by aerial photography is still an insufficiently developed part of geobotany. Here the morphological features of the plants themselves (the form of the corolla, and so forth) are used, of the study is based on topographical conditions, which method does not always give dependable results. Therefore, the development of a system of signs for interpretation and their accurate defining appears expedient.

In 1946 the author worked in the desert with aerial photographs on a scale of 1:10,000 and 1:20,000. The aim of this work was the use of phyto-coenotypes as indicators in geological investigations. One of the problems was seeking out the largest possible number of signs for interpretation of plant groups and their habitats.

Since an aerial photograph opens great possibilities for surveying vegetation in an area, in order to describe its contours, and to systematize the necessary measurements the author attempted to determine singular outlines produced by different types of vegetation, and to use these outlines for interpretation. This problem has been investigated only slightly and mainly for tundras. For conditions in Central Asia this method may give definite results, as witness the investigations by I. I. Gantov in Fyandzh, where he succeeded in surveying the district surrounding the Vakhsh River.

Investigations were conducted in two directions. One of these, which may be designated as morphographic, included a description of the external outlines and the internal structure of aerial photographic images of related groups.

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The other, or morphometric direction, included the different ways of measuring the quantitative characteristics of distribution of the vegetation derived by on-the-spot measurements and measurements on the photographs.

The object of the studies was vegetation of both the ancient and present lake basins in the deserts of Kyzyl-kum and Kara-kum. In Kyzyl-kum, studies were made in the basins lying to the south of the Khala-ata hills, the basins between the Uzun-kuduk well, and the Donguz-tau elevation (named Uzur-kudukskoy in its extremity), and in the Agytma, Mynbulak, Aygyrbulak, Dzharakuduk, and Sor-bulak basins. Of the extant lakes, the Su-yar-gan to the east of the city of Turtkul', Sultan-sandzhar on the eastern border of Kara-kum and Akkacha-kul at the base of Mt Sultan-uiz-dag were studied. Besides these, a visit was made to the Barsakel' mes basin at Ust'-urt.

The basic elements of the vegetation here were the following groups of phyto-coenotypes: (a) growths of different species of Tamarisk; (b) growths of *Nitraria Schoberi* L. and *Lycium Turcomanicum* F et M.; (c) growths of different succulent halophytes -- chiefly *Halocnemum strobilaceum* M. B. and *Kalidium foliatum* Moq. Tand; (d) growths of *Suaeda physophora* Pall; (e) black haloxylon, *Haloxylon aphyllum* Iljin.

From the point of view of their form and structure in aerial photographs, all the designated coenotypes may be divided into the following two groups:

1. Coenotypes, parts of which have a characteristic external shape and specific internal structure easily visible in aerial photographs.

2. Coenotypes, parts of which lose characteristic shape and discernible structure in photographs. Their characteristic form may be shown not so much by description, as by quantitative characteristics of distribution of the plants.

The characteristic representatives of the first group are growths of different species of the genus *Tamarix* (chiefly *T. hispida* Willd., *T. Karelinae* Bge.). They were characteristic both as to form and structure and displayed so many close ties between morphology of contour and character of habitat that they might serve for identifying their habitat.

Firstly, there was prominent a large group of curved contours, round or elliptical, which genetically were always linked with no-outlet, dried-up or drying lake beds. These included two types: (a) contours in the form of wide, intensely dark, continuous circles, that is, devoid of visible internal structures, sometimes concentrically encompassing one another, and (b) contours in the form of narrow circles, consisting of separate bushes far removed from one another, which in photographs became a fine dotted line. The first type was linked with active basins, the second with ancient dried-up basins.

Another group formed contours which appeared as more or less straight bands or lines. Among these, also, two varieties were distinguished: the first, represented by continuous dark bands, was associated with continuous or intermittent surface streams; the second, represented by bands or lines of separate, usually, rather large, bushes, situated on the hills, marked zones of subsurface water along various tectonic lines. This type of tamarisk growth on the hills, the latter known locally as "chukalak", was especially well marked in the photographs due to the large size of the hills and bushes, characteristic patterns similar to beads, and rather well-defined rectilinearity.

The zone of distribution of succulent saltwort, *Halocnemum strobilaceum*, *Kalidium foliatum*, described by many authors for dried-up lake basins, was also well marked in the photographs due to the difference in the intensity of the green color of the saltwort. In the 1:10,000 photographs a characteristic fine-grained structure could be observed inside the contours of both *Halocnemum* and *Kalidium*.

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Growths of *nitraria* and *Lycium turcomanicum*, fairly thick in the lake basins, were without specific outlines in the photograph. They appeared as distinctly visible accumulations, not contiguous one with another, spotted blurs, each one a single bush. An entire section occupied by these coenotypes may have the most varied contours.

In the same way, neither *haloxylon* nor *Jordia* growths had sufficiently definite markings in the picture, either in regional outlines or in internal formation. Therefore, for characteristics of their structure it was necessary to resort to measurements.

The tendency to characterize a biological coenotype by distribution of its component organisms has existed for a long time. Some geobotanists, particularly of the Moscow school, used for the characteristic of structure of phyto-coenotypes, curves which may be called curves of distribution. This method was used by the author in his research.

The application of this method to an analysis of aerial photographs of wood and brush desert vegetation is advantageous in that here we deal chiefly with dispersed coenotypes which are separated by definite intervals and are represented on the photograph as separate dots. This permits comparing measurements made on the ground with measurements in the photographs. The selection of material was made thus: in one plant group section, not less than 100 measurements were made of the distances between plants; measurements were made from one plant to all others of its type with which it could be joined in a straight line not crossing a specimen of the same species; then the next one was taken and so on until the necessary number of measurements was obtained. In every basin, the measurements were made in four or five localities, taking into account the similarity in topographical and soil conditions. The measurements obtained were divided into classes. The class interval was chosen for the most part with such calculation that it would be discernible on the photograph, and so that the data obtained in the area might be compared with the data obtained from the photograph. Therefore, this method was used only for species where the distance between specimens was sufficiently great, on the average not less than 2.5 meters. The result was a table from which could be seen what percent of the distances between specimens pertained to one class, what percent to another, and so forth. From this data it was possible to plot the curve of distribution, plotting the classes on the axis of the abscissas, and the percentages of the measured distances of a given class on the axis of the ordinates.

The first thing we succeeded in establishing by way of comparison of measurements obtained was a certain similarity in the distribution of one and the same species under similar conditions of habitat in the various basins. Thus, for example, there may be cited the following data on the distribution of *Suaeda physophora* Pall. in different parts of Kyzyl-kum in percentages:

Class of Distance (in m)	0-2.50	2.51-5.0	5.01-7.50	7.51-10.0	10.01-12.50	12.51-15.0
Basin						
Myn-bulak	26	54	14	6	--	--
Dzhara-kuduk	29.0	40.5	20.0	9.7	0.4	0.4
Usna-kuduk	30	36	26	8	--	--

A notable similarity was observed also between the distribution of tamarisk plants at similar stages of development of the chukalak in various regions:

Class of Distance (in m)	0-10.0	10.01-20.0	20.01-30.0	30.01-40.0	40.01-50.0
Area					
Kol Chukalak					
Rayon (SW of Kyzylkum)	52	33	10	2	3
Akhcha-kul' Rayon	52	35	6	5	2

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The reasons for this uniformity are hard to explain fully at present but it is probable that one is the comparatively simple formation of the coenotypes studied: they all represent growths of one species (rarely two or three), and with the similarity of conditions of habitat the distribution here is regulated essentially by the dimensions of a fundamental spore. In more highly organized coenotypes with complex interrelationships, the continuity of distribution may be more limited.

For the simple types of vegetation studied it appeared possible to set up several empirical schemes of average distribution in the form of tables or graphs. These schemes reflected the average picture of the distribution of a given species in specific habitats and could be employed in the interpretation of habitats on aerial photographs in the nature of auxiliary signs. Identification of habitat can be illustrated by examining the following two cases.

On the chukalak formed in areas with active subsurface waters, the tamarisk can be distributed in several ways. On the small recently-formed hills, its distribution by distance class in percentages can be represented by the following average quantities (classes of distances given in meters):

0-10m	10.1-20	20.1-30	30.1-40	40.1-50	50.1-60	60.1-70
21%	43.3	18.6	8.6	4.3	1.3	2.9

According to the growth of the hills in height and in diameter, by virtue of the accumulation of sand, salts, and organic substances, and by the increased branching out of the bushes strewn about the hill, the distances between the individual specimens are decreased. For the fully formed large hills we have the following average picture of the distribution of tamarisk:

0-10m	10.1-20	20.1-30	30.1-40	40.1-50	50.1-60	60.1-70
63%	26	6.1	3.2	1	0	0.7

After measuring the distances between the spots which represent individual bushes on the aerial photograph, and after determining the quantitative character of their distribution, it is possible to determine, according to the degree of similarity with one of the two schemes cited, which phase of chukalak development a given portion of the aerial photograph represents. After establishing the phase of hill development, it is possible to make a series of conclusions about their dimensions, the relative level of subsurface waters, and the character of the soil and the herbaceous vegetation, because all these landscape elements are different in the two phases defined.

In the approaches to the Amu Darya strip it is noticeable, in the case of the dark haloxylon in the depressions (Takyry), that there is a change in the character of distribution, depending on whether or not the surface of the depression is free of alluvium. Takyry is an apparently local designation for circular or elongated depressions covering up to several square kilometers. They collect thaw waters in spring and dry up in summer, presenting a crystalline, parquet appearance due to the substances carried by the water. This change can be represented by the following figures (averages from measurements in eight different areas):

Class of Distance (in m)	0-5.0	5.1-10.1	10.1-15.1	15.1-20.1	20.1-25.1	25.1-30.1	30.1-35.1	35.1-40.1	40.1-45.1	45.1-50.1
Location		10	15	20	25	30	35	40	45	50
Bare depressions	19.2	15.2	18.3	16	12.3	8.5	3.8	1.0	1.9	3.8
Depressions with alluvium	72	28	0	0	0	0	0	0	0	0

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Therefore, having determined the distribution of haloxylon from the photograph, it is possible to find out the character of the surface of the depression.

Great importance can hereby be attached to the question of the similarity of data on distribution, as obtained from measurements taken on the ground and data obtained from the photographs. Upon comparing the data obtained from both sources, it was shown that for Haloxylon aphyllum and species of Tamarix there was satisfactory agreement even in the case of photographs at a scale of 1:20,000. Satisfactory correspondence for Nitraria Schoberi, Lycium turcomanicum, and Suaeda physophora was achieved only on the 1:10,000 photographs.

Upon analyzing the vegetation as depicted on the aerial photograph it is often necessary to detect faint and little noticed features of plant distribution. The author endeavored to make use of the calculation of the coefficient of dispersion for this. This idea was introduced in the statistics of Lexis and Dornay and in the biology of Svedberg. In the field of statistics it is determined by the degree of stability of statistical series. It is expressed here as the manner in which the majorities of a species are grouped on the defined areas (studied by us) around the normal majority.

The coefficient of dispersion is determined by the ratio:

$$\frac{\sigma}{\bar{v}^2} : \frac{1}{\bar{v}}$$

where σ equals the average quadratic variation and \bar{v} equals the normal majority.

If the species is distributed on the surface with no definite pattern, the ratio will be one, or close to it--this would be a case of normal dispersion. If the distribution of the species is spotty--concentrated in some instances and sparse in others, the coefficient of dispersion will be more than one (above normal dispersion). If the species is distributed more uniformly, conforming more closely to some pattern, the coefficient will be less than one (below normal dispersion). In this study there was particular interest in the appearance of instances of above-normal dispersion, indicating an unequal distribution.

The determination of the coefficient of dispersion requires a calculation of majority for not less than 100 sectors, and it is difficult in woody and brushwood vegetation to conduct ground measurements. Aerial photography removes this obstacle by permitting a quick calculation of important dimensions. We conducted calculations on photographs with scales of 1:10,000 and 1:20,000; sectors of 50x 50 meters were used in the first instance, and sectors of 100 x 100 meters in the second. Calculations were made with the aid of a magnifying glass on an area selected at random.

The application of the coefficient of dispersion made it possible to be discriminating in several complex instances. Mention has already been made of the overgrowth of tamarisk bushes in the form of little chains and bands at the outlets of subsurface waters along tectonic lines and formation contacts. Usually these overgrowths are immediately recognizable by their peculiar linear configuration; however, at times recognition is quite difficult and the researcher has no guarantee that his recognition is not, in reality, a subjective conclusion.

Solving a similar problem, the author determined the coefficient of dispersion for two neighboring sections of overgrowth, one section of which seemed completely uniform as to distribution while the other had only a faintly perceptible and highly disputable striation. The first section, which served as a standard of visible uniformity, had a coefficient of 1.8; the second section, 5.92. Thus, the irregularity of distribution of the tamarisk in the second section received a quantitative expression.

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The above-mentioned phases of development of the chains of hills were likewise expressed in the gradual increase of the coefficient of dispersion--from 1.28 in the first phase to 1.72 in the second. This apparently is explained by the growth in the diameter of the hills in the direction exposed to prevailing winds and by the dying off of the tamarisk.

Upon analyzing the structure of the outlines of the overgrowths of *Nitraria*, *Schoberia*, and *Lycium turcomanicum* under various conditions, it was possible to establish the following: In overgrowths formed near active subsurface waters, the presence of large bushes, more than 2.5 meters in diameter, situated on the hills and distributed quite irregularly around the homogeneous background of the sparser bushes, is characteristic. The coefficient of dispersion for these large specimens is 8.5. However, it is not always possible to observe the irregularity of their distribution on the photograph and, therefore, the above normal dispersion figure appears to be the only reliable characteristic.

The material presented permits formulation of the following brief conclusions.

1. The pattern set up by the vegetation on the aerial photograph can serve as a criterion for identifying several types of habitats and the vegetation itself. This criterion seemed most adapted to the interpretation of hydrogeological conditions.
2. The pattern can be described in terms of the singularity of outlines and structure attributed to hydrogeological conditions.
3. In those instances when a qualitative or more precise report is difficult, an aerial photo representation of vegetation can be characterized by quantitative indexes: by the distribution of specimens and by the coefficient of dispersion.

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